

Surfactant Enhanced Aquifer Remediation (SEAR) for NAPL Contamination

It may be amusing to some that surfactants, which have been used in many of our daily household cleansers for decades, are finally being put to use for the remediation of our hazardous waste sites. One could ask, if water alone could handle everything, as is being attempted with pump and treat, where would we be with all of our fragrant soaps and detergents? It'd be a drab world indeed! SEAR as a concept is really not much different than the use of soapy water to soak the dirty clothes clean. And we all know that works....most of the time!

Pump and treat is probably familiar lingo to most involved in site remediation, but what is SEAR? It is an enhancement to the pump and treat technology which uses surfactants to clean up regions of an aquifer containing non-aqueous phase liquids (NAPLs).

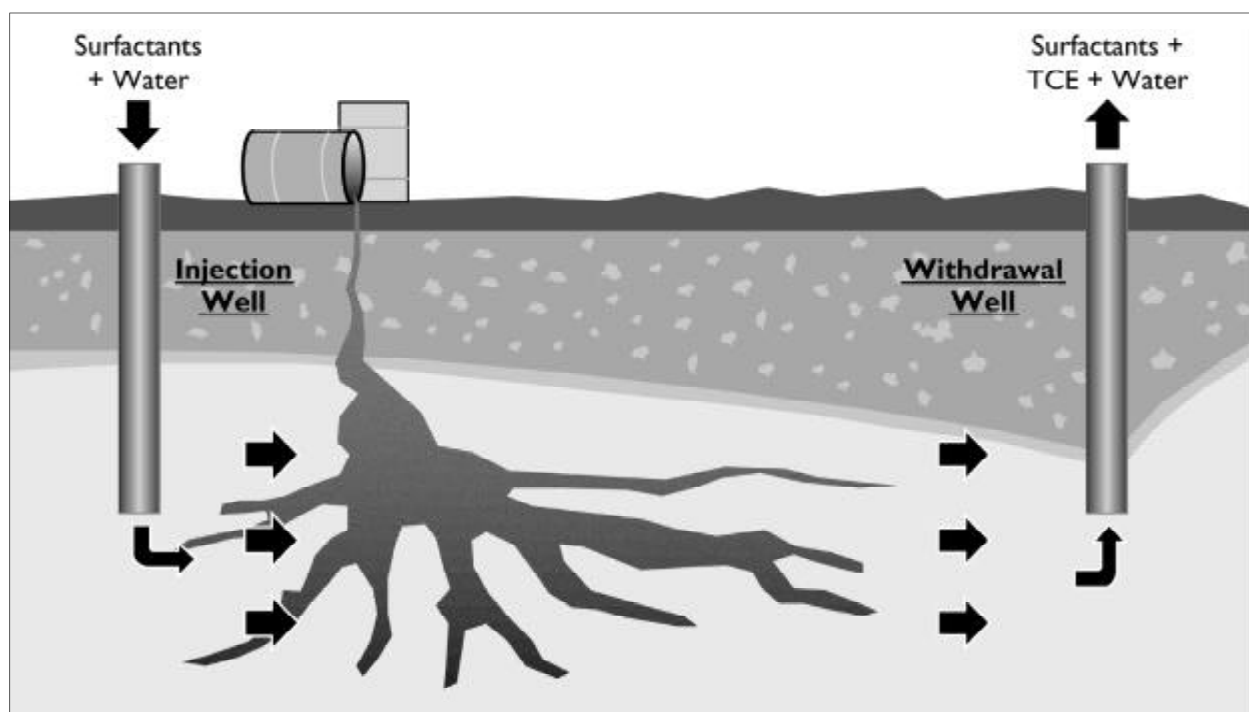
NAPL contaminants exist as a separate organic phase rather than in the dissolved

(aqueous)-phase. They are commonly found in the vicinity of the original spill or leak where they have become trapped by capillary and sorptive forces. Because they typically have low water solubilities, removal by pump and treat alone can take decades; yet without addressing them, site cleanup cannot be achieved. The problem posed by NAPLs is that with time they will slowly dissolve; therefore, so long as they remain in the subsurface, they act as a continual source of contamination to the surrounding soils and groundwater.

NAPL contaminants that are denser than water, also known as DNAPLs, are especially troublesome because they tend to sink into the saturated zone, for which there are few alternatives for remediation. SEAR is unique in its ability to effectively address saturated zone contamination. Probably the most well known DNAPL contaminants are the chlorinated solvents, such as trichloroethylene (TCE) and perchloroethylene (PCE). These compounds

not only have low aqueous solubilities, but also biodegrade very slowly.

What are surfactants and how can they enhance aquifer remediation? Surfactants are a class of molecules which form aggregates called micelles. Micelles start forming at a concentration specific to each surfactant, known as the critical micelle concentration (CMC). Surfactant micelles provide a favorable environment into which organic molecules can partition, thus increasing their effective aqueous solubility. The surfactants used in SEAR are non-toxic, food-grade, and biodegradable. Salts, and sometimes alcohols are added to adjust the surfactant properties, i.e. to improve the uptake of NAPL and/or the hydraulic properties such as the viscosity of the surfactant solution. When applied to subsurface contaminants, surfactants operate in a manner which is analogous to the way detergents (which contain surfactants) remove oil and grease from clothin and dishes. Basically, the



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surfactants assist in transferring the unwanted organic matter from the material that is being cleaned (aquifer solids) into the water phase where they can be washed away.

The method by which surfactants are administered in the aquifer is simple. The surfactant solution is prepared in tanks above-ground, and then injected into the aquifer. The surfactants and NAPL are removed at the extraction wells. Hydraulic control of the surfactant and NAPL is maintained by using higher pumping rates at the extraction wells than at the injection wells and by the selective placement of water injection wells.

SEAR is applied in the following steps: first the suspected source area must be delineated to determine the lateral and vertical extent of NAPL contamination. This is accomplished by the installation of soil borings and monitoring wells. Soil and groundwater samples are collected to characterize the aquifer material and groundwater for NAPL and other chemical constituents, as well as for hydraulic parameters. In addition to assisting in the

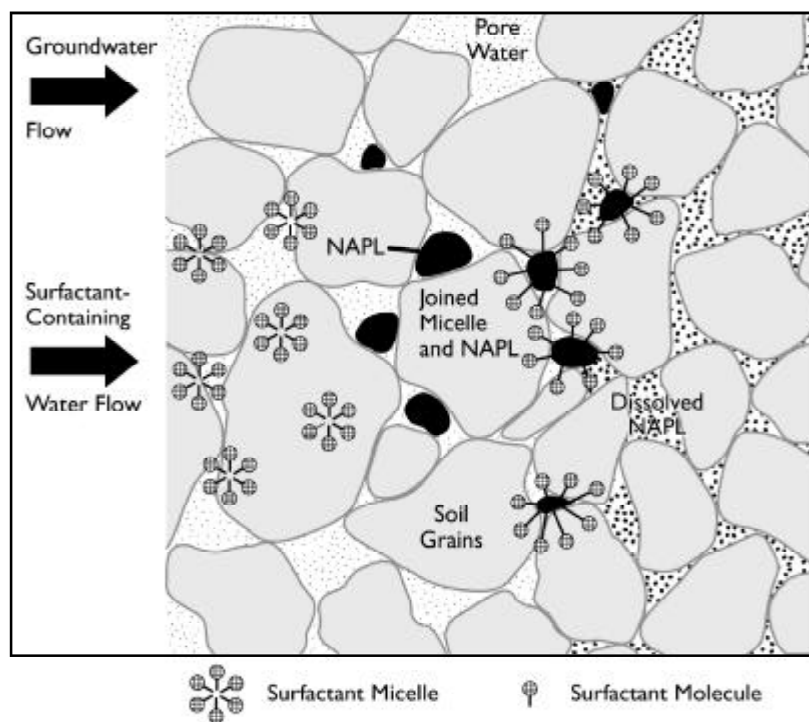
identification of the likely boundaries of the NAPL zone, these aquifer properties are needed to select the appropriate surfactant and for the hydrogeologic design of the surfactant test. An additional tool for site characterization which is useful for obtaining more detailed information on the quantity of NAPL in the subsurface is a partitioning interwell tracer test (PITT). During a PITT, conservative or non-partitioning tracers, which remain in the water phase and move with the velocity of the water, are injected simultaneously with non-conservative or partitioning tracers, which partition between the water and NAPL phase and thus become retarded by the presence of NAPL. By analyzing the recovery of both types of tracers at the recovery wells with time, the amount of NAPL in the zone swept by surfactants can be determined. If free-phase NAPL is present at the site, it is removed prior to the PITT if it is performed; otherwise, it is removed prior to the introduction of surfactants.

Between two to ten pore volumes of surfactant solution (including salt and alcohol, if used) are used to flush the

NAPL-contaminated aquifer. This is followed by water flushing to remove residual surfactant and NAPL. If a PITT was conducted initially, another PITT is then conducted to determine the quantity of NAPL (if any) remaining in the aquifer. By comparing the NAPL saturations before and after the surfactant test, the efficiency of NAPL removal can be determined. Additional core sampling can also be used to confirm the removal of NAPL from the surfactant-flushed zone.

In 1996, several surfactant demonstrations have been successfully completed at Hill Air Force Base (north of Salt Lake City, Utah). At Operable Unit (OU) 1, four test cells (approx. 3 m x 5 m each) which were physically isolated with sheet piling, were used to examine the effectiveness of various surfactants for extracting a complex NAPL. At OU 2, a DNAPL site, a larger test (6 m x 6 m) was conducted without the use of sheet-piling. Instead containment of the solubilized DNAPL was achieved hydraulically. In these field tests, two to ten pore volumes of water containing surfactant at concentrations above the CMC (approx. 2-8 wt%), and in some cases, salt and alcohol additives, were used to flush the contaminated region. NAPL recoveries as high as 99% were reported.

Currently, NFESC and the U. S. Environmental Protection Agency's National Risk Management Research Laboratory (EPA/NRMRL) are funded under the Environmental Security Technology Certification Program (ESTCP) to evaluate the benefits of recovering and recycling surfactant for the overall economics of applying SEAR.



Surfactant NAPL Interaction

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